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(54) **Optical multiplexer/demultiplexer**

Optischer Multiplexer/Demultiplexer

Multiplexeur/demultiplexeur optique

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- **5th European Conference on Integrated Optics, Paris, France, Proceedings ECIO'89, Volume 1141 SPIE, Washington, Y. Bourbin et al.: "Monolithically integrated multi/demultiplexer and access waveguides in InGaAsP/InP", pp 59-66**
- **ELECTRONICS LETTERS, vol. 24, no. 5, 3 March 1988, Stevenage, GB, pp265-266; E. GOTTWALD AND J. PIETZSCH: 'MEASUREMENT METHOD FOR DETERMINATION OF OPTICAL PHASE SHIFTS IN 3x3 FIBRE COUPLERS'**

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Description

Background of the Invention

Field of the Invention

This invention relates to an optical diffractor, which in many embodiments, will be used as a multiplexer/demultiplexer.

Description of the Prior Art

Optical multiplexing and demultiplexing is normally accomplished by means of a dispersive element, such as a diffraction grating, prism, hologram, etc. One such optical multiplexer/demultiplexer is described in the article "A Six-Channel Wavelength Multiplexer and Demultiplexer For Single Mode Systems" by J. Lipson et al. in Journal of Lightwave Technology, Vol. LT-3, No. 5, October 1985. In the Lipson article, a blazed diffraction grating is utilized for combining and separating various wavelengths of light. Demultiplexing is accomplished by transmitting the multiplexed signal through the grating, which separates the individual wavelengths of light and diffracts each in a slightly different direction. Multiplexing is accomplished by utilizing the same device in reverse; i.e., shining each wavelength through the grating at a predetermined wavelength dependent angle such that all the wavelengths emerge essentially as one single multiplexed beam of light. A similar device is disclosed in GB-A-2219869.

This conventional grating, which has been widely utilized in optical communications systems, has several drawbacks. First, some of the incident power is usually lost, because a grating with a period less than half the wavelength of the incident light produces unwanted higher order modes in unwanted directions. Second, due to current manufacturing technology, gratings have limited resolution i.e., wavelengths within 5 Angstroms of each other will not normally be separated. Finally, the grating is typically combined with a lens or reflector to focus the light, and the lens or reflector is difficult to implement in integrated form using, for example, photolithographic techniques.

Several proposals have previously been made in an attempt to overcome the above problems. One optical multiplexer which overcomes the above problems to some extent is described in the article, "New Focusing and Dispersive Planar Component Based on an Optical Phased Array", by M. K. Smit, in Electronic Letters, 1988, Vol. 24, pp. 385-386. In the Smit article, a plurality of optical waveguides are utilized, each of a different length, to construct an optical phased array. The resulting structure acts as a high resolution optical multiplexer. However, due to the fact that there is essentially no mutual coupling among the waveguides, the structure is highly inefficient.

A.R. Vellekoop and M.K. Smit, in 'A Small-Size Polarization Splitter Based on a Planar Optical Phased Array', *Journal of Lightwave Technology,* vol. 8, no. 1, p118-124, January 1990, disclose a polarization splitter which uses an array of concentrically bent optical waveguides to split a signal consisting of mixed TE and TM modes on an input waveguide to separate TE and TM signals on respective output waveguides. They mention that the array could also be used as a wavelength (de)multiplexer. The preamble of claim 1 bases on this paper.

Summary of the Invention

According to the invention there is provided an optical multiplexer/demultiplexer as set out in claim 1. Preferred forms are set out in the dependent claims.

Brief Description of the Drawing

FIG. 1 shows an exemplary embodiment of the inventive multiplexer/demultiplexer;
FIG. 2 shows an enlarged view of two exemplary waveguide arrays of FIG. 1; and
FIG. 3 shows two refractive profiles, defined in more detail hereafter.

Detailed Description

FIG. 1 shows an exemplary embodiment of the invention comprising eleven waveguides 101-111, arranged into four waveguide arrays 112-115, each of which defines a substantially circular arc. The arc formed by waveguide array 112 is part of a circle which has its center along waveguide array 115. Further, the arc formed by waveguide array 115 is part of a circle which has its center along waveguide array 112. Waveguide arrays 113 and 114 are arranged similarly.

Waveguide arrays 113 and 115 can only be used effectively within their respective Brillouin zones, whose width 2γ is specified by:

$$\sin\gamma = \frac{1}{2}\frac{\lambda}{a_o} \qquad (1)$$

where a_o is the distance between waveguide centers at the larger opening of the waveguides as shown in FIG. 2 and λ is the wavelength of the incident light. It should be noted that the multiplexer/demultiplexer will be utilized with differing wavelengths, and consequently, the width of the Brillouin zone will not be a constant for all incident light.

Returning to FIG. 1, the waveguides 106-108 are arranged to occupy a predetermined fraction of the Brillouin zone of waveguide array 115. The fraction of the Brillouin zone occupied is denoted herein as the field of view, and has width 2 γ_0 as shown in FIG. 2. Waveguides 109-111 of FIG. 1 occupy the field of view of waveguide array 113.

For purposes of clarity, operation of the device will be first described as if only one of waveguides 106-108 of waveguide array 112 is excited. The use of the device as a multiplexer/demultiplexer will then be explained.

Waveguides 101-105 are each of a different length, and each differs in length from its adjacent waveguide by a fixed amount denoted 1. Consider a wave of wavelength λ_0 emanating from waveguide 106 toward waveguides 101-105, where λ_o and 1 are chosen such that 1 is an integer multiple of λ_o. Due to the difference in length from waveguide 106 to each of waveguides 101-105, the phase of the emanating wave as it is received by each of waveguides 101-105 will be different. More particularly, the wave will be received by waveguide 101 at some reference phase 0, while being received at waveguides 102, 103, 104 and 105 at phase ϕ, 2ϕ, 3ϕ and 4ϕ respectively.

As the wave propagates along the tapered region of the waveguides of waveguide array 115, it is gradually transformed into five separate uncoupled waves, with such transformation causing near zero higher order mode generation. Each of the five uncoupled waves will then propagate along its respective waveguide until reaching waveguide array 113.

At waveguide array 113, the five waves are gradually coupled back into a single propagating wavefront, which emanates toward waveguide array 114. Since 1 is an integer multiple of λ_0, the constant phase difference ϕ between adjacent waveguides is preserved. Thus the wave emanating from each of the waveguides of waveguide array 113 is phase shifted by ϕ from the wave emanating from its neighboring waveguide.

The five waves will combine to produce a single wavefront which propagates in a direction that corresponds exactly to the direction along waveguide array 112 from which the wave was launched. More particularly, a wave launched from waveguide 106 will be directed by waveguide array 113 toward waveguide 109, since waveguides 106 and 109 are disposed in corresponding positions of their respective waveguide arrays 112 and 114. Similarly, waves which are launched from waveguides 107 or 108, will be directed by waveguide array 113 at waveguides 110 and 111, respectively. This is due to the fact that waveguides 107 and 110 are located in corresponding positions of their respective waveguide arrays 112 and 114, as are waveguides 108 and 111.

Note that as the waves propagate along their respective waveguides, the phase of the wave in any waveguide is substantially unaffected by the phase of the wave in any other waveguide. This is due to the lack of coupling of the waveguides throughout their lengths, which allows each wave to propagate independently. Further, if the wavelength of the incident light is not an integer multiple of the path length difference 1, this independent propagation allows the phase relationship among the five waves to change as the waves propagate through the waveguides. This property allows construction of a multiplexer/demultiplexer as described below.

Assume that 1 is not an integer multiple of the wavelength. In this case, energy launched from one of waveguides 106-108 of waveguide array 112 will not be directed by waveguide array 113 toward the corresponding waveguide along waveguide array 114. A wave launched from waveguide 106, for example, would not be directed by waveguide array 113 towards waveguide 109 of waveguide array 114, even though waveguide 109 and waveguide 106 are in corresponding positions of their respective waveguide arrays 112 and 114. Rather, the direction of the wave when it emanates from waveguide array 114 will be displaced laterally by some predetermined amount D. The amount of displacement D, is a function of the wavelength of the wave and is specified by

$$D = \frac{R}{a_0}\frac{\lambda - \lambda_0}{\lambda_0} l \qquad (2)$$

where R is the radius of the arc defined by waveguides 101-105, λ_0 is the nearest wavelength to λ such that 1 is an integer multiple of λ_0, and 1 and a_0 are as previously defined.

Thus, it can be seen that if a wave comprising a plurality of wavelengths is launched from waveguide 106, each of the wavelengths will emanate in a different direction from waveguide array 113. This property can he utililized to build a demultiplexer. More particularly, consider a wave comprising wavelengths λ_1, λ_2, and λ_3 launched from waveguide 106, for example, toward waveguide array 115 of FIG. 1. Equation 2 can be utilized to arrange waveguide array 114 such that each of the wavelengths λ_1, λ_2, and λ_3 is directed toward a separate one of waveguides 109-111.

This can be done by calculating D for each wavelength and positioning waveguides 109-111 accordingly. Further, if each of the waveguides 106-108 is excited with a different wavelength, the different wavelengths can be selected so that they all emanate into the same one of waveguides 109-111.

Having established the basic principles of operation it may be desired to improve the efficiency of the multiplexer/demultiplexer. In order for the efficiency to be close to unity, the receiving waveguides must almost touch each other, so that essentially the entire incident power is collected. Thus, the initial separation ℓ in FIG. 2 must be very small. In order for the power received by waveguide array 115 to be transferred efficiently to waveguide array 113, the waveguides in waveguide array 115 must include a transition in which the separation ℓ between waveguides gradually increases. If the field of view γ_0 is appreciably smaller than γ, for instance,

$$|\gamma_0| < 0.5\gamma \tag{3}$$

then efficiencies close to unity will be obtained by simply using a linear transition, characterized by a linear variation of ℓ, with

$$L > 60\,\frac{a_0}{\lambda} \tag{4}$$

where L is the length of the transition. For some applications, however, the required field of view may exceed 0.5 γ. Then, the above length must be increased, and the required increase can be calculated by means of the standard design formulae of waveguide tapers. In order to obtain, for instance, efficiencies exceeding 90 percent for $|\gamma_0| > 0.75\gamma$, one must choose $L > 200\frac{a_0}{\lambda}$. Much larger L will be required for $|\gamma_0|$ much closer to γ. It will then become important to use, instead of a linear taper, a more efficient taper which can be designed as follows.

FIG. 2 shows an enlarged view of waveguide arrays 112 and 115 of FIG. 1. The parameters c, c', a and t will be described hereafter. The larger openings of the waveguides define an arc on a circle. The longitudinal axes of the waveguides intersect at the center of the circle.

FIG. 3 shows a plot of

$$n^2a^2\left[2\frac{\pi}{\lambda}\right]^2 \tag{5}$$

as a function of the position along a cross section of FIG. 2, where n is the index of refraction at the particular point in question, λ is a wavelength of the light being used to excite the waveguide array, and a is the distance between waveguide centers. Traversing the horizontal axes labeled z=c and z=c' in FIG. 3 is equivalent to traversing the arcs c and c', respectively, of FIG. 2. For purposes of explanation, equation 5, plotted for any circular cross-section of FIG. 2 such as those labeled c and c', is referred to herein as a refractive profile.

Everything in equation 5 is constant for a given refractive profile, except for n, which will oscillate up and down as the waveguides are entered and exited respectively. Thus, each plot is a periodic square wave with amplitude proportional to the square of the index of refraction at the particular point in question along an arc.

Note that once the diameter of the arc formed by each waveguide array is determined, specifying the refractive profiles at closely spaced intervals along the longitudinal axes of the waveguides will uniquely determine the taper shown at the end of each waveguide in FIG. 2. The closer the intervals, the more accurate the design of the taper. Specifying this taper correctly will maximize the efficiency of the waveguide array by reducing the amount of energy in unwanted higher order modes.

The correct property to be satisfied by each refractive profile is that its first order Fourier coefficient, denoted V, should essentially satisfy the condition

$$V = 2\pi^2\left[\frac{\sin\gamma - \sin\theta_B}{\sin\gamma}\right]\left[\frac{p(y)}{\sqrt{1-p^2(y)}}\right] \tag{6}$$

where θ_B is an arbitrary angle within the central Brillouin zone,

$$p(y) = 3\,\frac{y}{2}\,(1-\frac{1}{3}\,y^2),$$

$y = F_r(\frac{|z|}{L})+F_t$, L is equal to the length of the tapered region excluding the dashed portion as shown in FIG. 2, F_r and F_t are the fractions of the waveguide remaining and truncated, respectively, and |z| is the distance from the wider end of the waveguide to the point where the refractive profile intersects the longitudinal axis of the waveguide. The length of the waveguide before truncation would include the dashed portion of each waveguide, shown in FIG. 2. This can be calculated easily since, at the point when the waveguides are tangent, (z=t in FIG. 2), V will equal 0 as the plot

$$n^2a^2\left[\frac{2\pi}{\lambda}\right]^2$$

is a constant. Thus, by finding the point z=t along a z axis such that V=0, one can determine the length before truncation. The length after truncation will be discussed later herein, however, for purposes of the present discussion, F_t can be assumed zero, corresponding to an untruncated waveguide. It can be verified that for an arrangement such as that of FIG. 2,

$$V = \frac{(n_1+n_2)(n_1-n_2)}{4\pi}\,k^2a^2\sin(\frac{\ell\pi}{a}) \tag{7}$$

where n_1 and n_2 are the refractive indices inside and between the waveguides respectively, and $k = \frac{2\pi}{\lambda}$. Thus, from equations 6 and 7:

$$\left[\frac{\sin\gamma-\sin\theta_B}{\sin\gamma}\right]\left[\frac{p(y)}{\sqrt{1-p^2(y)}}\right] = \frac{(n_1+n_2)(n_1-n_2)}{4\pi}\,k^2a^2\sin(\frac{\ell\pi}{a}) \tag{8}$$

Thus, after specifying θ_B and assuming F_t equals zero, equation 8 can be used to specify ℓ at various points along the z axes and thereby define the taper of the waveguides.

Throughout the above discussion γ_0, θ_B, and F_t were assumed to be design parameters which were selected independently. In actuality, these three parameters interact in a complex manner to influence the performance of the multiplexer/demultiptexer. The following discussion is provided to clarify the interaction of γ_0, θ_B, and F_t.

One figure of merit M for a waveguide array which emanates towards a second waveguide array, is described by the following equation:

$$M=N^2(\gamma_0)\,\frac{\sin\gamma_0}{\sin\gamma} \tag{9}$$

where $N(\theta)$ is calculated by using the following set of equations:

$$v = \int_0^z (B_o - B_1)dz \tag{10}$$

$$\tau = \int_0^{v_L} t\,\exp(jv)dv \tag{11}$$

$$t = \frac{a^2}{2}\,\frac{B_0(\sin\gamma)^2}{4\pi^4(\sin\gamma-\sin\theta)^2}\,\frac{dV(z)}{dz}\,\frac{1}{(1+u^2)^{3/2}} \tag{12}$$

where

$$u = \frac{\sin\gamma}{2\pi^2 \left[\sin\gamma - \sin\theta\right]} \left[V(z)\right] \qquad (13)$$

$$N(\theta) = \frac{1}{1+|\tau|^2} \qquad (14)$$

In the above equations B_0 and B_1 represent the propagation constant, of the fundamental mode and first higher order mode, respectively, of the waveguides, v_L is equal to equation 10 evaluated at z = L, and θ is any angle less than or equal to γ_0. In practice, θ should be set to γ_0, since this case represents the worst case performance within the field of view.

To maximize M the procedure is as follows: assume F_t=0, choose an arbitrary θ_B, and calculate N using equations 6 and 10-14 with θ equal to γ_0 for all angles γ_0 within the central Brillouin zone. Having obtained these values of $N(\gamma_0)$, determine which γ_0 maximizes M. This gives the maximum M for a given F_t and a given θ_B. Next, keeping F_t equal to 0, iterate the above process using all θ_Bs. This gives the maximum M for a given F_t over all θ_Bs. Finally, iterate the entire process with various F_ts until the maximum M is achieved over all θ_Bs and F_ts. This can be carried out using a computer program.

It is to be understood that the above described example is for illustrative purposes only and that other variations are possible without violating the scope of the invention. For example, optional delay elements 116-120 could be inserted into the waveguides, as shown in the dashed outline in FIG. 1. The delay elements, which alter the effective length of the waveguide, could be used either in addition to or instead of the physical length differences in the waveguides. For purposes of explanation herein, the length of a waveguide includes any apparent additional length caused by the delay elements. Finally, the delay elements allow external control of the lengths by means of a control signal.

The device can be utilized as a switch rather than a multiplexer/demultiplexer. More particularly, the input to any waveguide can be shifted in wavelength to correspond to a desired output waveguide toward which it is desired to emanate the wave. The device can be fabricated on a single chip, using photolithographic techniques which are well-known in the art.

Claims

1. An optical multiplexer/demultiplexer comprising a plurality of N optical waveguides (101-105), each waveguide including a first end for receiving optical energy and a second end for transmitting optical energy,

each waveguide further being of a predetermined different length substantially equal to $l + n\ell$, where l is a predetermined initial length, n is an integer such that $0 \le n \le N - 1$, and ℓ is a predetermined value greater than zero, the waveguides being substantially coupled to each other at their respective first ends, and at their respective second ends, and substantially uncoupled therebetween such that a single wavefront of optical energy incident upon the first ends is transformed within the waveguides to a plurality of substantially uncoupled propagating waves, and the plurality of uncoupled propagating waves is transformed into substantially a single propagating wavefront when reaching the second ends,
wherein the first ends of each waveguide are arranged into a first waveguide array (115) to substantially define a first arc, and wherein the second ends of the waveguides are arranged into a second waveguide array (113), to substantially define a second arc,

CHARACTERIZED BY:

an input array (112) including:
a plurality of waveguides (106-108), each including a first end for receiving optical energy, and a second end for launching the optical energy, said second ends being arranged to substantially define a third arc, said third arc defining a portion of a circle which has its centre on said first arc.

2. An optical multiplexer/demultiplexer of claim 1 further comprising:

an output array (114), including:
a plurality of waveguides (109-111), each including a first end for receiving optical energy, and a second end for launching the optical energy, said second ends being arranged to substantially define a fourth arc, said fourth arc defining a portion of a circle which has its centre on said second arc.

3. The optical multiplexer/demultiplexer of claim 1 or claim 2 wherein the first end and the second end of each waveguide of said N optical waveguides includes a tapered portion.

4. The optical multiplexer/demultiplxer of claim 3 wherein the tapered portion includes a first end and a second end and wherein at least one of said arrays includes a series of refractive profiles, thereby defining the shape of the taper, each refractive profile comprising a first order Fourier coefficient, each first Fourier coefficient substantially equal to:

$$V = 2\pi^2 \left[\frac{\sin\gamma - \sin\theta_B}{\sin\gamma}\right] \left[\frac{p(y)}{\sqrt{1-p^2(y)}}\right]$$

where 2γ is an angle defining a central Brillouin zone associated with the array, θ_B is an arbitrary angle less than or equal to γ, p(y) is substantially equal to

$$3\frac{y}{2}(1 - \frac{1}{3}y^2), \text{ where } y = F_r \left\{\frac{|z|}{L}\right\} + F_t,$$

z is the distance from the second end of the waveguides to the refractive profile, $F_t = \frac{L+b}{L}$, b is the distance which the outer surface of each waveguide would have to be extended from the second end to become tangent to an adjacent waveguide and $F_r = 1 - F_t$.

5. The optical multiplexer/demultiplexer of claim 4 wherein at least one of said N optical waveguides comprises a delay element (116-120) for increasing its path length.

Patentansprüche

1. Optischer Multiplexer/Demultiplexer umfassend eine Vielzahl von N-optischen Wellenleitern (101 bis 105), wobei jeder Wellenleiter ein erstes Ende zum Empfangen optischer Energie und ein zweites Ende für das Senden von optischer Energie umfaßt, wobei jeder Wellenleiter ferner von einer vorbestimmten unterschiedlichen Länge, im wesentlichen gleich I + n1 ist, wobei I eine vorbestimmte Anfangslänge, n eine ganze Zahl derart, daß $0 \leq n \leq N-1$ ist, und 1 ein vorbestimmter Wert größer als 0 ist, wobei die Wellenleiter im wesentlichen an ihren jeweiligen ersten Enden und an ihren jeweiligen zweiten Ende aneinander gekoppelt sind, und dazwischen im wesentlichen ungekoppelt sind, so daß eine einzelne Wellenfront von optischer Energie, die auf die ersten Enden auffällt, in den Wellenleitern in eine Vielzahl von im wesentlichen ungekoppelten, sich ausbreitenden Wellen transformiert wird, und wobei die Vielzahl von ungekoppelten, sich ausbreitenden Wellen beim Erreichen der zweiten Enden im wesentlichen in eine einzelne, sich ausbreitende Wellenfront transformiert wird, wobei die ersten Enden jedes Wellenleiters in einem ersten Wellenleiterfeld (115) angeordnet sind, um im wesentlichen einen ersten Bogen zu definieren, und wobei die zweiten Enden der Wellenleiter in einem zweiten Wellenleiterfeld (113) angeordnet sind, um im wesentlichen einen zweiten Bogen zu definieren,
gekennzeichnet durch:

ein Eingangsfeld (112) umfassend:
eine Vielzahl von Wellenleitern (106 bis 108), von welchen jeder ein erstes Ende zum Empfangen von optischer Energie und ein zweites Ende zum Freigeben bzw. Einspeisen der optischen Energie umfaßt, wobei die zweiten Enden angeordnet sind, um im wesentlichen einen dritten Bogen zu definieren, wobei der dritte Bogen einen Abschnitt eines Kreises definiert, der sein Zentrum am ersten Bogen hat.

2. Optischer Multiplexer/Demultiplexer nach Anspruch 1, ferner umfassend:

ein Ausgangsfeld (114), umfassend:
eine Vielzahl von Wellenleitern (109 bis 111), die jeder ein erstes Ende zum Empfangen von optischer Energie und ein zweites Ende für das Freisetzen bzw. Einspeisen der optischen Energie umfassen, wobei die zweiten Enden angeordnet sind, um im wesentlichen einen vierten Bogen zu bilden, wobei der vierte Bogen den Abschnitt eines Kreises, der sein Zentrum am zweiten Bogen hat, bildet.

3. Optischer Multiplexer/Demultiplexer nach Anspruch 1 oder 2, bei welchem das erste Ende und das zweite Ende jedes Wellenleiters der N-optischen Wellenleiter einen sich verjüngenden Abschnitt umfaßt.

4. Optischer Multiplexer/Demultiplexer nach Anspruch 3, bei welchem der sich verjüngende Abschnitt ein erstes Ende und ein zweites Ende umfaßt, und bei welchem wenigstens eines von den Feldern eine Serie von Brechungsindexprofilen umfaßt, wobei die Form der Verjüngung definiert wird, wobei jedes Brechungsindexprofil einen Fourier-Koeffizienten erster Ordnung umfaßt, wobei jeder Fourier-Koeffizient erster Ordnung im wesentlichen gleicht:

$$V = 2\pi^2 \left[\frac{\sin\gamma - \sin\theta_B}{\sin\gamma}\right] \left[\frac{p(y)}{\sqrt{1 - p^2(y)}}\right]$$

wobei 2γ ein Winkel ist, der eine mittige Brillouin-Zone definiert, die dem Feld zugeordnet ist, θ_B ein willkürlicher Winkel ist, der kleiner oder gleich γ ist, p(y) im wesentlichen gleich:

$$3\frac{y}{2}(1 - \frac{1}{3}y^2), \text{ where } y = F_r \left\{\frac{|z|}{L}\right\} + F_t,$$

ist, wobei z der Abstand zum zweiten Ende der Wellenleiter zum Brechungsindexprofil ist, $F_t = \frac{L+b}{L}$ b der Abstand ist, welchen die äußere Oberfläche jedes Wellenleiters haben würde zum Erweitern des zweiten Endes, um an einem benachbarten Wellenleiter anzuliegen, und $F_r = 1 - F_t$ ist.

5. Optischer Multiplexer/Demultiplexer nach Anspruch 4, bei welchem wenigstens einer der N optischen Wellenleiter ein Verzögerungselement (116 bis 120) zum Erhöhen seiner Wegstrecke umfaßt.

Revendications

1. Multiplexeur/démultiplexeur optique comportant une pluralité de N guides d'onde (101 à 105) optiques, chaque guide d'onde ayant une première extrémité destinée à recevoir de l'énergie optique et une seconde extrémité destinée à transmettre de l'énergie optique,

chaque guide d'onde étant en outre d'une longueur différente prédéterminée sensiblement égale à $l + n\ell$, où ℓ est une longueur initiale prédéterminée, n est un entier tel que $0 \leq n \leq N-1$, et ℓ est une valeur prédéterminée supérieure à 0, les guides d'onde étant sensiblement couplés les uns aux autres à leur première extrémité respective, et à leur seconde extrémité respective, et sensiblement non couplés entre celles-ci de sorte qu'un front d'onde unique d'énergie optique incident aux premières extrémités est transformé dans les guides d'onde en une pluralité d'ondes de propagation sensiblement non couplées, et la pluralité d'ondes de propagation non couplées est transformée en sensiblement un seul front d'onde de propagation lorsqu'elles atteignent les secondes extrémités,
dans lequel les premières extrémités de chaque guide d'onde sont disposées en un premier réseau (115) de guides d'onde pour définir sensiblement un premier arc et dans lequel les secondes extrémités des guides d'onde sont disposées en un second réseau (113) de guides d'onde, de manière à définir sensiblement un second arc,

caractérisé par :

un réseau (112) d'entrée comportant:
une pluralité de guides d'onde (106 à 108), qui comportent chacun une première extrémité pour recevoir de l'énergie optique et une seconde extrémité pour envoyer l'énergie optique, ces secondes extrémités étant disposées de manière à définir sensiblement un troisième arc, ce troisième arc définissant une partie d'un cercle qui a son centre situé sur le premier arc.

2. Multiplexeur/démultiplexeur optique suivant la revendication 1, qui comporte en outre:

un réseau (114) de sortie comprenant:
une pluralité de guides d'onde (109 à 111), qui comportent chacun une première extrémité pour recevoir de l'énergie optique, et une seconde extrémité pour envoyer l'énergie optique, ces secondes extrémités étant disposées de manière à définir sensiblement un quatrième arc, ce quatrième arc définissant une partie d'un cercle qui a son centre situé sur le second arc.

3. Multiplexeur/démultiplexeur optique suivant la revendication 1 ou la revendication 2, dans lequel la première extrémité et la seconde extrémité de chaque guide d'onde des N guides d'onde optiques comportent une partie en biseau.

4. Multiplexeur/démultiplexeur optique suivant la revendication 3, dans lequel la partie en biseau comporte une première extrémité et une seconde extrémité et dans lequel au moins l'un des réseaux comporte une série de profilés de réfraction, qui définissent ainsi la forme du biseau, chaque profilé de réfraction ayant un coefficient de Fourier du premier ordre, chaque premier coefficient de Fourier étant sensiblement égal à

$$V = 2\pi^2 \left[\frac{\sin\gamma - \sin\theta_B}{\sin\gamma}\right] \left[\frac{p(y)}{\sqrt{1 - p^2(y)}}\right]$$

où 2γ est un angle définissant une zone de Brillouin centrale associée au réseau, θ_B est un angle arbitraire inférieur ou égal à γ, p(y) est sensiblement égal à

$$3\frac{y}{2}(1 - \frac{1}{3}y^2), \text{ où } y = F_r\left(\frac{|z|}{L}\right) + F_t,$$

z est la distance qui sépare la seconde extrémité des guides d'onde au profilé de réfraction, F_t est égal à $\frac{L+b}{L}$, b est la distance dont devrait être étendue la surface extérieure de chaque guide d'onde à partir de la seconde extrémité pour devenir tangente à un guide d'onde adjacent et F_r est égal à 1 - F_t.

5. Multiplexeur/démultiplexeur optique suivant la revendication 4, dans lequel au moins l'un des N guides d'onde optiques comporte un élément (116-120) à retard destiné à augmenter sa longueur de trajet.

FIG. 1

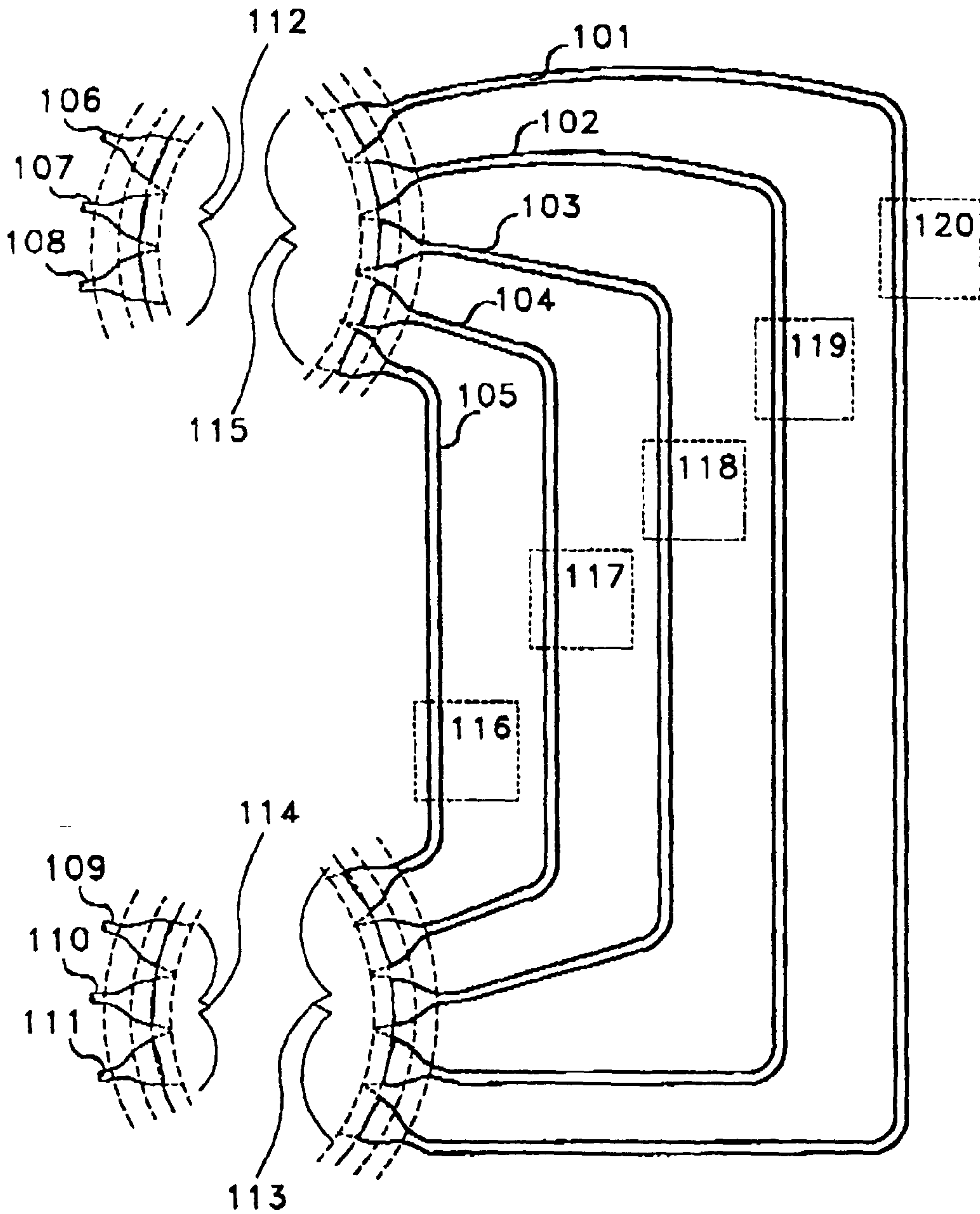
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FIG. 2

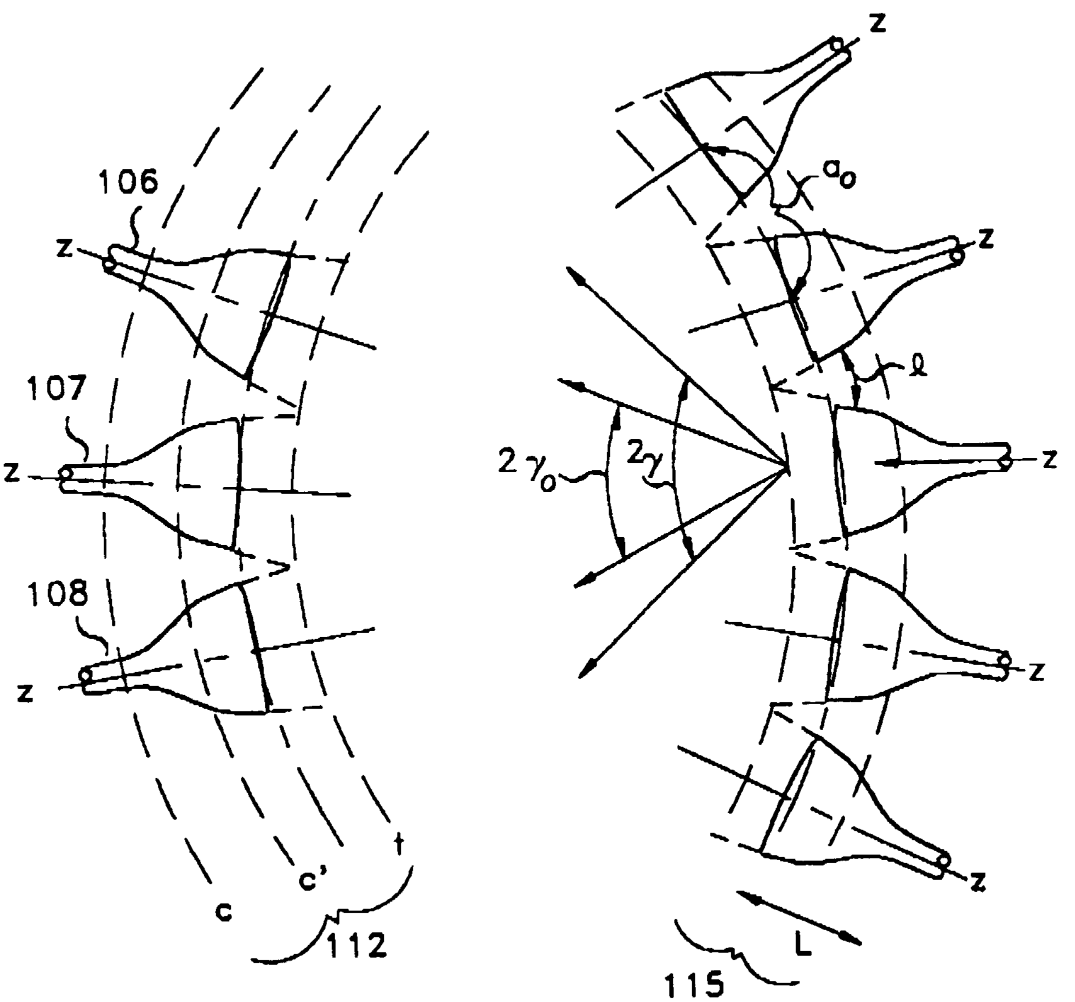

FIG. 3